DOSIMETRY SUPPORT OF THE UKRAINE-US "SCIENTIFIC PROTOCOL FOR THE STUDY OF THYROID CANCER AND OTHER THYROID DISORDERS IN UKRAINE FOLLOWING THE CHORNOBYL ACCIDENT"

(2nd quarter report, Parts 8.7, 8.28, 8.29, 8.30)

1999-2000

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8.7. PERSONAL QUESTIONING OF COHORT MEMBERS IN THE PROCESS OF SCREENING. DOSIMETRY SUPPORT OF MEDICAL INVESTIGATIONS. EXPANSION AND SUPPORT OF PERSONAL QUESTIONNAIRE DB FOR COHORT MEMBERS

Throughout the second quarter of investigation 1999-2000 (period from September 1999 to November 1999) collection of dosimetry questionnaires continued as mobile teams pursued their work and in the process of examination of cohort members at the Institute of Endocrinology and Metabolism. A total of 861 questionnaires have been collected, among which 629 have been entered into computer database. 3 persons were found as not belonging to the cohort. It has been found out during the process of interviewing that the location of one person at the moment of the accident was the city of Kyiv, and not the village Chornogorod of Chornobyl raion which was indicated in activity measurement database. This person has been registered in the village of Chornogorod because his grand-mother was residing then in this village. The issue of whether to left or not this person in the cohort, should be resolved by the DCC.

Table 8.7.1 gives distribution of questionnaires collected in the last quarter and entered into computer DB according to the age of cohort members at the moment of the accident and raions of residence during the accident.

Table 8.7.2 gives distribution of collected questionnaires by raions of residence at iodine stage of the accident and by dose groups.

After an analysis of questionnaires collected in the 2nd quarter 1999, 5 persons have been revealed with incorrect membership identification in the cohort. Two of these persons are to be included in the cohort, but under another ID (and, therefore, with another result of thyroid activity measurement). Table 8.7.3 gives a list of persons with ID codes which have been given by mistake.

Table 8.7.1 By-age and by-raion distribution of personal questionnaires collected in the 2nd quarter

Raion	Age, years				**Total**
	0-4	**5-9**	**10-14**	**15-18**	
Narodychi	1	3	0	2	6
Îvruch	5	6	16	2	29
Ivankiv	0	1	0	1	2
Polisya	1	6	2	3	12
Chornobyl	3	2	9	9	23
Prypyat'	27	34	23	10	94
Kozelets	2	1	7	5	15
Ripky	2	2	6	2	12
Chernihiv raion	146	89	78	16	329
City of Chernihiv	43	35	21	4	103
Kyiv	0	1	0	0	1
Total	230	180	162	54	626

Table 8.7.2 By-dose and by-raion distribution of personal questionnaires collected in the 2nd quarter

Raion	Dose groups			**Total**
	A	**B**	**C**	
Narodychi	0	2	4	6
Îvruch	13	15	1	29
Ivankiv	1	0	1	2
Polisya	3	3	6	12
Chornobyl	9	5	9	23
Prypyat	12	22	60	94
Kozelets	7	3	5	15
Ripky	6	3	3	12
Chernihiv raion	99	105	125	329
City of Chernihiv	66	28	9	103
Kyiv	1	0	0	1
Total	217	186	223	626

Table 8.7.3. – List of persons with incorrect ID codes from questionnaires collected in the 4th quarter

Surname in 1986	Surname in 1998	First name	Patronymic	ID	ID-correct	Member of the cohort
				03604720		No
				01299930		No
				02395423		No
				10739121	08760526	Yes
				04082317	03548121	Yes

8.28. ANALYSIS OF ANSWERS RECEIVED DURING THE INTERVIEWING PROCESS

8.28.1. Comparative analysis of questionnaires collected in 1992 and 1999

8.28.1.1. Description of questionnaire information files to be compared

In order to estimate the quality of questionnaire information, questionnaires collected in 1992 with the purpose of clarifying the features of behavior of the population at iodine stage of the accident, have been used. A computer linkage has been performed between Project questionnaires (3893 questionnaires) and questionnaires collected in 1992 among inhabitants of Chernihiv oblast (9385 questionnaires). Practically, two linked questionnaires provide information on the behavior of the same person in April-May 1986, which has been collected in different periods. The main criteria of computer linkage of questionnaires are the following:

- Surname, First name, Patronymic
- Year of birth
- Settlement of location at the moment of the accident
- Settlement of location at the moment of interviewing
- Complete address at the moment of interviewing if available (in questionnaires collected in 1992 the address was not always indicated)

A total of 206 questionnaires were found to be linked.

The questionnaire used in 1992 was somewhat different, as to its structure, from that being used at present. Therefore, comparison has been performed only for those information blocks which are available in questionnaires of 1992 and 1999. The main blocks for which comparison of questionnaire information has been performed, are the following:

- Source of milk being consumed
- Quantity of milk being consumed
- Leafy vegetable consumption (for three (ten-day) periods of May 1986)
- Stable iodine taking
- Settlements of residence at iodine stage of the accident
- Sanitary countermeasures against iodine (restriction of walks).

We will furtherly call the questionnaires collected in 1992 "group 1 questionnaires", and Project questionnaires "group 2 questionnaires".

8.28.1.2. Source of milk

Table 8.28.1 gives distribution of questionnaires depending on the number of sources of milk consumption.

Table 8.28.1. Distribution of questionnaires of both groups (1 and 2) depending on the number of sources of milk consumption.

Questionnaire group	Consumption from one source		Consumption from several sources		Information on milk consumption source unknown	
	Number	%	Number	%	Number	%
Group 1	204	99	0	0	2	1
Group 2	193	94	13	6	0	0

The analysis of the coincidence of information for the block "milk source" is represented in Table 8.28.2. The Table gives the % of questionnaires with different degree of coincidence of information on milk source: complete, partial coincidence, and lack of coincidence.

"Partial coincidence" is introduced in order to compare information on milk source in case of consumption from several sources. A partial coincidence was registered in cases where two or more milk sources were indicated in one questionnaire, and in another one only a part of these sources was indicated.

It follows from the above data that information on the source of consumed milk is well reproducible, coinciding in 73% of cases.

Table 8.28.2. Coincidence of information in group 1 and 2 questionnaires for the block "milk source"

Complete coincidence		Partial coincidence		Lack of coincidence		Information on milk source unknown	
Number of questionaires	%	Number of questionaires	%	Number of questionaires	%	Number of questionaires	%
140	68	9	4	55	27	2	1

8.28.1.3. Quantity of consumed milk

Table 8.28.3 shows distribution of questionnaires depending on the presence or absence of the fact of milk consumption.

Table 8.28.3. Distribution of questionnaires of both groups depending on the presence or absence of the fact of milk consumption.

Questionnaire group	Consumption		Lack of consumption		Information unknown	
	Quantity	%	Quantity	%	Quantity	%
Group 1	182	88	0	0	24	12
Group 2	185	90	10	5	11	5

At a first stage, it has been performed a comparison of information concerning the presence or absence of the fact of milk consumption (Table 8.28.4).

Table 8.28.4. Comparison of information concerning the presence or absence of the fact of milk consumption

Coincidence				Lack of coincidence		Information unknown	
Fact of consumption		Fact of non-consumption					
Quantity	%	Quantity	%	Quantity	%	Quantity	%
164	80	0	0	9	4	33	16

Table 4 points out that the fact of milk consumption at iodine stage of the accident is well reproducible in case of repeated interviewing.

It has been performed for the questionnaires with nonzero milk consumption a comparison of information on the quantity of consumed milk and the difference was estimated. With this purpose the mean value of difference in the quantity of milk consumed per day (DEV) has been calculated by the following formula:

$$\mathrm{DEV}=\frac{1}{N_q}\sum_{i=1}^{N_q}\sqrt{\frac{1}{N_d}\sum_{j=1}^{N_d}(x_{ij}-y_{ij})^2} \qquad (1)$$

where

x_{ij}	Quantity of consumed milk on j-th day indicated in the i-st questionnaire of Group 1, litres per day;
y_{ij}	Quantity of consumed milk on j-th day indicated in the i-st questionnaire of Group 2, litres per day;
Nd	Number of days;
Nq	Number of questionnaires with nonzero milk consumption.

As a result we have obtained DEV=0.46 l per day. Therefore, the mean deviation in the quantity of milk consumed per day, when comparing the questionnaires of groups 1 and 2, is almost equal to 0.5 l. And there was no correlation between the mean level of milk consumption in the same individual in the questionnaires for 1992 and those for 1999. The correlation factor made up –0.04. Thus, information on mean level of milk consumption is not reproducible in subsequent questioning.

8.28.1.4. Consumption of leafy vegetables

Table 8.28.5 demonstrates distribution of group 1 and 2 questionnaires regarding the fact of leafy vegetable consumption for three (ten-day) periods of May 1986.

Table 8.28.5. Distribution of Group 1 and 2 questionnaires regarding the fact of leafy vegetable consumption

Period of May 1986	Consumption		Nonconsumption		Information unknown	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
1.05 – 10.05	171	170	35	36	0	0
11.05 – 20.05	168	171	38	35	0	0
21.05 – 31.05	163	171	40	35	3	0

Table 8.28.6 gives the results of a comparison of information on the fact of leafy vegetable consumption.

Table 8.28.6. Comparison of information on leafy vegetable consumption.

Period of May 1986	Coincidence				Lack of coincidence		Information unknown	
	Fact of consumption		Fact of nonconsumption					
	Quantity	%	Quantity	%	Quantity	%	Quantity	%
1.05 – 10.05	149	72	14	7	43	21	0	0
11.05 – 20.05	149	72	16	8	41	20	0	0
21.05 – 31.05	144	70	16	8	43	21	3	1

Information on consumption (or refusal to consume) leafy vegetables is well reproducible in subsequent questioning, coinciding on the average in 79 % of questionnaires.

8.28.1.5. Stable iodine taking

The fact of stable iodine taking was noted in 13 questionnaires of Group 1 (questioning of 1992). In questionnaires of group 2 (questioning of 1999) the fact of stable iodine taking is noted only in one questionnaire. For all questionnaires of group 1, in which stable iodine taking was noted, in linked questionnaires of group 2 information on stable iodine taking is missing. It is difficult to draw some conclusions as to the reproducibility of information on stable iodine taking, since the number of such questionnaires is very small in the sample of linked questionnaires under study.

8.28.1.6. Settlements of residence at the time of the accident

An analysis of information about the place of residence during the accident has been performed for the period 26.04.86 to 31.05.86, equal to 36 days. For each day from this period a comparison of settlements has been made for two linked questionnaires. Then, it has been calculated, for each couple of linked questionnaires, the number of days for which the settlements have coincided. On the average, for all linked questionnaires this number was equal to 34.6. The percent of reliability of information reproducibility regarding the place of residence at iodine stage of the accident, made 34.6/36*100=96%.

Changing in place of residence at iodine stage of the accident (relocation to another settlement) has been registered in 30 questionnaires of group 1 and 20 questionnaires of group 2. For the questionnaires in which the fact of relocation to another settlement was indicated, the mean number of days with coinciding settlements was equal to 28.8. The percent of reliability of information reproducibility regarding relocations obtained as a result of repeated questioning, made 28.8/36*100=80%.

8.28.1.7. Sanitary antiiodine countermeasures

The questionnaires of Group 1 included questions concerning the use in the period after the accident, of the following sanitary measures: frequent wet cleaning of rooms, more frequent washing of the body, change of clothes, restriction of walks, closing of windows. For group 2 questionnaires the list of antiiodine countermeasures included the following ones: restriction of walks and reduction of milk consumption. In connection with differences in the list of countermeasures for both groups of questionnaires, comparison of information for the division "Sanitary countermeasures" was possible only for the countermeasure "restriction of walks". The Table 8.28.7 shows distribution of questionnaires concerning the fact of use (or non-use) of the countermeasure "restriction of walks".

Table 8.28.7. Distribution of questionnaires concerning the fact of use (or non-use) of the countermeasure "restriction of walks"

Questionnaire group	Use		Non-use	
	Number	%	Number	%
Group 1	59	29	147	71
Group 2	35	17	171	83

The results of comparison of information concerning the fact of use and non-use of the countermeasure "restriction of walks" are presented in Table 8.28.8.

Table 8.28.8. Comparison of information concerning the fact of use and non-use of the countermeasure "restriction of walks"

Coincidence				Noncoincidence	
Fact of use		Fact of non-use			
Number	%	Number	%	Number	%
9	4	121	59	76	37

The data given point out that, as compared to the group 1 questionnaires, in group 2 questionnaires the fact of use of such a countermeasure as "restriction of walks" was noted much more rarely, and the percent of coincidence of information in both questionnaire groups concerning use of this countermeasure is very low (4%). Therefore, reproducibility of information concerning restriction of walks at iodine stage of the accident is not good: near 40% of questionnaires do not reproduce this information in case of repeated questioning.

8.28.2. Analysis of questionnaire quality: (a) Are the answers to all questions satisfactory ? (b) What kind of questions would be still necessary ?

Among the information blocks in question, the more reproducible one in the process of repeated later questioning is the information on the source of milk consumed and on the fact of consumption (or nonconsumption) of milk and leafy vegetables at iodine stage of the accident. A satisfactory coincidence was noted between the data on relocations to other settlements in April-May 1986.

Information on the quantity of milk consumed is of poor quality, being inaccurate. It is almost not reproducible during repeated questioning.

Indeed, the most difficult in the process of questioning is the necessity of giving in the answers a quantitative information: on mean levels of milk and leafy vegetables' consumption, on the number of hours spent in the open air. Without special indications as to probable levels of consumption (one liter, half a liter or one glass), it is very diffcult to get this information.

In our opinion, the following questions are to be added to the Ukrainian questionnaire:

- Does the respondent remember thyroid activity measurement or not? For those who remembers measurement, to add the question: (a) was the subject washed before counting, (b) was the neck wiped using an alcohol/other solution just before counting?
- Have such general protective sanitary countermeasures been used as: (a) more frequent body washing, (b) more frequent wet cleaning of rooms, (c) frequent change of clothes?
- Have the respondent been attending: (a) creche/kindergarten, (b) school in the iodine stage of the accident, was he (c) at home, (d) in a pioneer summer camp / sanatorium / rest home?
- Origin of preparations of stable iodine in case of its taking by the respondent: (a) acquired on his own, (b) distributed by medical workers at his place of residence, (c) distributed at school, kindergarten.

- The date of beginning of dairy animals pasturing in Spring 1986 should be included in the questionnaire (this question is to be addressed to the parents who come to the interview with their children), because in the process of questioning a number of villages in Chernihiv oblast have been identified, where pasturing began late in Spring 1986, what was due to a flood of Desna-River.
- The question whether the adult residents remember the fact of rains that took place in the settlement of residence in the period from April 26 to the May 6, 1986.

We also consider it necessary to change the general design of the questionnaire.

8.29. INTERCOMPARISON EXERCISE: ESTIMATION OF THE THYROID DOSES FOR 5 OR 10 HYPOTHETICAL INDIVIDUALS

8.29.1. Analysis of scenarios for 10 hypothetical individuals

Table 8.29.1 gives the scenarios proposed for intercomparison of results of dose calculations. The analysis is divided into 2 stages. At a first stage, one should estimate activities of ^{131}I in thyroid gland of each subject on the day of counting on the basis of the results of power of exposure dose measured on thyroid, abdomen levels, and in the room in the absence of the patient. It is also necessary to estimate the uncertainty of estimates of thyroid activity obtained.

At a second stage, one should estimate the thyroid exposure dose of each subject taking into account the scenario of his exposure, provided that thyroid activity on the day of counting, equal to 50 kBq, is known. Besides, it is necessary to estimate the uncertainties of the dose estimates obtained.

Òàble 8.29.1. Scenarios for calculating activities, doses and uncertainties of their estimates

Information Category	Subject A	Subject B	Subject C	Subject D	Subject E	Subject V	Subject W	Subject X	Subject Y	Subject Z
Date of birth	22 Sept 80	4 May 76	10 Jun 85	12 Dec 74	3 Jan 70	15 Sept 85	20 Nov 84	24 Apr 83	30 Oct 81	4 July 79
Place of residence: Conaminated	village	city	village	village	village	city	village	city	village	village
Date of measurement (Reference Date)	18 May	14 May	25 May	20 May	10 May	27 May	8 May	22 May	15 May	12 May
Measured exposure rates (μR/h)										
Thyroid	2750	780	570	1820	2360	600	2200	430	550	220
Abdomen	300	250	400	350	100	450	80	350	200	150
Room background	25	20	35	30	10	30	20	30	25	30
Subject washed before counting?	Yes	No	Don't know	No	Don't know	Yes	Yes	Yes	Yes	Yes
Respondent to questions	Mother	Older brother	Father	Grandmother	Self	Grandmother	Older Sister	Grandmother	Mother	Mpther
Milk consumption rate (L/d)?	0.8	1.0	0.6	0.5	2.0	0.6	0.5	0.5	0.8	0.0
Milk source(s)?	Family cow	Shops	Family Cow	Goat	Family cow	Shops	Family cow	Shops	Family cow	None
Change in milk consumption rate?	No	Yes	No	No	Yes	Yes	No	No	Yes	No
Date		5 May			10 May	4 May			4 May	
New rate (L/d)		0.3			0	0.2			0.4	
Date						13 May			8 May	
New rate (L/d)						0.6			0.2	
Took stable iodine tablets?	No	No	Yes	No	No	Yes	No	Yes	Yes	No
Start date			10 May			4 May		2 May	4 May	
End date			12 May			6 May		4 May	4 May	
Start date										
End date						11 May			8 May	

Table 8.29.1 Continued

Information Category	Subject A	Subject B	Subject C	Subject D	Subject E	Subject V	Subject W	Subject X	Subject Y	Subject Z
Leafy vegetable consumption?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rate (kg/d)	0.021	0.036	0	0.041	0.058	0.0034	0.0062	0.012	0.017	0.025
Change in leafy vegetable consumption rate?	No	No	No	No	Yes	No	No	No	Yes	No
Date					10 May				8 May	
New rate (kg/d)					0				0	
Date										
New rate (kg/d)										
Was subject relocated?	No	No	No	No	Yes	No	No	No	Yes	No
When					10 May				15 May	
Where					To clean city				To clean city	
Date dairy animals on pasture in area?	20 April	25 April	20 April	30 April	Does not know. 29.04 - 1.05 is estimated range	20 April	25 April	Does not know 28.04 –5.05 is estimated range	30 April	25 April
Date(s) of I-131 dep osition	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)	Amount (kBq/m2)
26 April	-	-	-	-	-	-	-	-	-	-
27 April	6000	200	-	100	1500	500	-	-	400	500
28 April	-	400	-	300	-	3000	2500	800	900	3000
29 April	-	1800	500	200	-	1200	-	300	300	2000
30 April	-	500	500	100	-	200	-	-	-	400

GOALS OF THE ANALYSIS

PART A: 1. Estimate thyroid activity (kBq) on the reference date

2. Estimate the uncertainty in thyroid activity

PART B: Assuming content on reference date is 50 kBq 3. Estimate thyroid dose (mGy) for scenario

4. Estimate the uncertainty in thyroid dose

8.29.2. Calculation of activity on the basis of the results of measurements

8.29.2.1. Main assumptions, models and design formulae

Main assumptions:

- In all the scenarios in question one assumes that nonspectrometric devices were used (results of measurement expressed in $\mu R\ h^{-1}$); for the Ukraine these are SRP-68-01 devices supplied with a collimator.
- In all the scenarios in question it is supposed that the result of measurement on the level of abdomen is available. In Ukraine measurement on the level of the abdomen were performed for the lower portion of the abdomen: the level of bladder. There- fore, hereinafter we are using the term "abdomen" for the "lower portion of the abdomen on the level of the bladder".
- Superficial contamination is supposed to be identical on all body parts.
- Washing before counting does not eliminate completely superficial contamination but decreases it, on the average.
- In case of answer "don't know" to the question of body washing before counting, one may suppose with a 50 % probability that washing took place.

The following models are assumed for the measurements of counting rates from thyroid (N_{th}) and abdomen (N_{ab}):

$$N_{th} = N_{th}^{J} + N_{th}^{Cs} + k_2 N_{bg} + N_{sc} \quad (1)$$

$$N_{ab} = N_{ab}^{Cs} + k_2 N_{bg} + N_{sc} \quad (2)$$

where

N_{th}= Counting rate of γ-radiation when counting on thyroid level, $\mu R\ h^{-1}$;
N_{ab}= Counting rate of γ-radiation when counting on abdomen level, $\mu R\ h^{-1}$;
N_{bg}= Counting rate of γ-radiation at the place of counting in the absence of the patient, $\mu R\ h^{-1}$;
N_{th}^{J} = Counting rate of γ- radiation - unobservable in measurements - from ^{131}I, when counting on thyroid level, which is to be estimated, $\mu R\ h^{-1}$;

N_{th}^{Cs}= Counting rate of γ-radiation - unobservable in measurements - from a mixture of Cs radioisotopes incorporated in the body, when counting on thyroid level;

N_{ab}^{Cs}= Counting rate of γ-radiation - unobservable in measurements - from a mixture of Cs radioisotopes incorporated in the body, when counting on abdomen level, $\mu R\ h^{-1}$;

N_{sc}= Counting rate of γ-radiation - unnobservable in measurements - from superficial body contamination (is supposed to be equal on all body portions), $\mu R\ h^{-1}$;

$k_2(a)$= Age-related factor of shielding by human body of γ-radiation in the room where counting is performed (may be estimated experimentally or according to literature data), dimensionless.

Unobservable values N_{th}^{Cs} and N_{ab}^{Cs} are linked by the following relationship:

$$N_{th}^{Cs} = k_1 N_{ab}^{Cs} \qquad (3)$$

where

k_1= Factor which takes into account the geometrical relationships when counting Cs radionuclides in the body on thyroid and abdomen levels (k_1 value may be estimated in an experiment with radiocaesium counting in the body in the absence of ^{131}I in environment), dimensionless.

The unobservable value of counting rate from superficial contamination (N_{sc}) may be represented through the counting rate from caesium radionuclides in the body as:

$$N_{sc} = r N_{ab}^{Cs} \qquad (4)$$

where

r= Relationship between the level of superficial contamination and radiocaesium content in the body when counting on abdomen level, dimensionless.

As regards r value, we have no own data; we may only suppose that this relationship depends on time $r(t)$ and is decreasing with time elapsed after the accident.

As follows from the above suggestions, $r(t)$ value is decreasing after washing, i.e. r also depends on the fact of washing before counting (w), decreasing on the average by k_w times, if the fact of washing is noted in the scenario. In case the subject does not remember his behavior before counting, one may assume with a 50% probability the fact of washing. Therefore:

$$r(t,w) = \left\{ \begin{array}{l} r(t), \text{ in case of answer "no" to the question about washing} \\ k_w\, r(t), \text{ in case of answer "yes" to the question about washing} \\ 0.5\,(1+k_w)\, r(t), \text{ in case of answer "do not know" to the question about washing} \end{array} \right\} \qquad (5)$$

where

k_w= Factor of decrease of counting rate from the abdomen after body washing, dimensionless.

As concerns k_w value, we have no own data.

Taking into account all the foregoing, the model (1) takes the following form:

$$N_{th}=N_{th}^{I}+N_{ab}\frac{[k_1+r(t,w)]}{[r(t,w)+1]}+N_{bg}\frac{k_2(1-k_1)}{[r(t,w)+1]}, \tag{6}$$

and the estimated value of counting from ^{131}I in case of measurement on thyroid level will be equal to:

$$N_{th}^{I}=N_{th}-N_{ab}\frac{[k_1+r(t,w)]}{[r(t,w)+1]}-N_{bg}\frac{k_2(1-k_1)}{[r(t,w)+1]} \tag{7}$$

It is easy to demonstrate that in the absence of superficial contamination ($r(t,w)=0$), the expression (7) takes the following form:

$$N_{th}^{I}=N_{th}-N_{ab}k_1-N_{bg}k_2(1-k_1) \tag{8}$$

and it exactly coincides with the formula given in [2]. In this case, the estimate of the value of counting from ^{131}I will be a maximum.

And if superficial contamination is very high ($r(t,w)>>1$), the expression (7) will tend to the following form:

$$N_{th}^{I}=N_{th}-N_{ab} \tag{9}$$

and the estimate of the value of counting from ^{131}I will be a minimum.

The following formula was used for calculating activity:

$$A\ (kBq)=37K_s\frac{K_{ov}(a)}{K_m(a)}N_{th}^{I}=37K_s\frac{K_{ov}(a)}{K_m(a)}\left\{N_{th}-N_{ab}\frac{[k_1+r(t,w)]}{[r(t,w)+1]}-N_{bg}\frac{k_2(a)(1-k_1)}{[r(t,w)+1]}\right\} \tag{10}$$

where

A= Thyroid activity on the day of counting, kBq;
K_s= Calibration factor of SRP-68-01 according to control source (bottle phantom of thyroid /mass = 10 g/ without tegumental tissues), in $\mu Ci\ \mu R^{-1}\ h$;

$K_{ov}(a)$= Age-related correction factor for taking into account gamma radiation absorption by the layer of tissues covering the thyroid, dimensionless;

$K_m(a)$= Age-related correction factor for taking into account self-absorption of radiation in the thyroid, dimensionless;

37 Factor for conversion activity from μCi into kBq;

$k_2(a)$= Age-related factor of shielding of γ-radiation by human body at the place of counting;

k_1= Factor taking into account the geometrical relationships when counting caesium radionuclides in the body on thyroid and abdomen levels;

N_{th}= Counting rate of γ-radiation when counting on thyroid level, $\mu R\ h^{-1}$;

N_{ab}= Counting rate of γ-radiation when counting on abdomen level, $\mu R\ h^{-1}$;

N_{bg}= Counting rate of γ-radiation at the place of counting in the absence of the patient, $\mu R\ h^{-1}$;

$r(t,w)$= Relationship between superficial contamination and radiocaesium content in the body when counting on abdomen level (depends on time elapsed from the 26.04.86 till the date of counting and on information about washing before counting according to (5)), dimensionless;

a= Subject's age at the moment of counting, years.

8.29.2.2. Influence of the geometry of measurement on device counting from $^{137,134}Cs$, contained in the body, when counting on thyroid and abdomen levels.

There are some literature data about the influence of the geometry of measurement on device readings when counting $^{137,134}Cs$ in the body (k_1 factor), but this information has a discrepant character. So, Zvonova I.A. et al. [1] note that when counting radiocaesium in the body with noncollimated SRP-68-01 devices, the relationship between counting on thyroid and hip levels is equal to 1.15±0.03 in children aged 0-7 years, and it makes 1 in children aged over 7 and in adults. In[2], for identic measurements in adults this relationship is equal to 0.85±0.05. The same work [2] contains results of estimates by Korelina N.F. of a factor that takes into account the geometrical correlations when counting neck and hip in children, which practically do not differ from estimates in adults. In case of location of noncollimated SRP-68-01 detector close to the neck and the middle of the hip, it has been obtained a relationship between counting rates of gamma radiation from caesium equal to 0.87±0.15 in children aged 1 to 8 years, and 0.9±0.16 in children aged 8 to 16 years.

In [3], we find an estimate of relationship of counting from radiocaesium in the body when counting with SRP-68-01 without collimator on thyroid and abdomen levels, equal to 0.875±0.026.

We have carried out special investigations in order to establish this relationship.

In order to determine the numerical value of k_1 factor, measurements have been performed in October-November 1999 in adolescents who are permanent residents of the village Stare Selo of Rokytniv raion of Rivne oblast and who were sent to the Clinic of the Scientific Center for Radiation Medicine (Kyiv) for a sanitation sojourn. Measurements have been performed on day 4 after children arrived to Kyiv. It has been selected 4 adolescents aged 11 to 15 years and weighing 35 to 51 kg (2 boys and and 2 girls) with the highest content of ^{137}Cs radionuclides in the body, measured at the moment of admission of children to the Clinic, by means of WBC (Table 8.29.1).

Table 8.29.1. - Anthropological parameters and activity of ^{137}Cs isotopes in the body of adolescents who have been selected for measurements.

Surname, First name	Sex	Age, years	Weight, kg	Height, cm	^{137}Cs activity in the body, nCi
P.I.	M	11	38	151	389
A.I.	F.	15	51	166	320
Ch.A.	M	12	35	147	307
P.L.	F	13	45	159	215

It has been used for measurements an SRP-68-01 device, S/N 5804, of the same type which was used for counting in 1986. The device has been checked at the Laboratory of Metrology of the Scientific Center of Radiation Medicine in 1999.

A special collimator has been made in order to reproduce the conditions of measurements in 1986, consisiting of a lead plate 4 mm thick and 250 mm wide, twice wrapped around the detector's pipe, so that the total thickness of walls was equal to 8 mm. The collimator bulged 5 cm out of the edge of detector unit.

Since ^{137}Cs activity in the body of adolescents selected for measurements is insufficient for measurements by means of SRP-68-01, the device has been improved in order to operate in pulse accumulation mode. A counting device PSO 5-2 has been connected to the jack of the headphone of SRP-68-01 through matching resistors. It calculated the number of coming pulses for a given time interval (a 200-s interval was used).

Measurements were performed in a protective chamber covered with lead from all sides. The background measured in the chamber was mostly a device background (noise), what is evidenced by the absence of a trustworthy difference in background level when counting using a device with and without collimator. Therefore, no factor of shielding of background by the body was introduced.

For each adolescent measurements were performed using a device with and without colliamtor. Provided relative error of 20%, the minimally detectable counting rate was equal to 0.45 pulse s^{-1}.

The results of measurements of counting rate from ^{137}Cs in case of measurements on the level of thyroid and lower portion of the abdomen using SRP-68-01 device with and without collimator, are given in Tables 8.29.2 and 8.29.3, respectively.

Table 8.29.2. Results of measurements of counting rate from ^{137}Cs in the body using SRP-68-01 with collimator

Person measured	Counting rate from thyroid, pulse s^{-1}	Counting rate from lower portion of the abdomen, pulse s^{-1}	Background, pulse s^{-1}	k_1
P.I.	1.42	1.60	0.57	0.83
P.L.	1.09	1.16	0.57	0.88
Ch.A.	1.35	1.63	0.57	0.74
A.I.	1.28	1.44	0.57	0.82

Table 8.29.3. Results of measurements of counting rate from ^{137}Cs in the body using SRP-68-01 without collimator

Person measured	Counting rate from thyroid, pulse s^{-1}	Counting rate from lower portion of the abdomen, pulse s^{-1}	Background, pulse s^{-1}	K_1
P.I.	5.32	6.66	0.60	0.78
P.L.	3.98	4.29	0.60	0.92
Ch.A.	5.08	6.24	0.60	0.79
A.I.	4.96	4.84	0.60	1.03

The mean value of k_1 factor in measurements with collimator was equal to 0.81±0.06; in measuements without collimator to 0.88±0.12. The mean value of k_1 obtained in measurements without collimator coincides with the estimate given in [3], under conditions of analogous measurements in adults using SRP-68-01 device without collimator (0.875±0.026).

For calculations of activity according to the formula (10), the value of k_1 factor equal to 0.81 was used, assuming a lognormal distribution of this factor with GM=0.81 GSD=1.039.

8.29.2.3. Factor of shielding by human body of background in a room.

The estimates of the value of the factor of shielding by human body of background in a room (k_2 factor), found in literature, coincide well.

In [1], on adult volunteers a factor has been obtained for SRP-68-01, which does not trustworthily differ for the neck and hip, being equal to 0.93±0.03. Besides, it is indicated that this factor depends on anthropometrical indices of the person examined, and it may vary from 0.75 (a corpulent man weighing 85-100 kg) to 0.95 (a child weighing 10-15 kg) in case of measurements on abdomen level.

In [3], these factors for natural sources of γ-radiation (more high-energy than a scattered radiation from a mixture of nuclear accident's radionuclides in May 1986) practically do not differ in persons when counting on thyroid and abdomen levels, but are decreasing with increasing height and weight from 1.00 for children aged under 14 year to 0.95 for adolescents aged 14 to18 years, and to 0.90 for people aged over 18 years.

In order to estimate the factor of shielding of γ-background by human body in a room, we have performed a series of measurements in one adult subject (weight 68 kg, height 174 cm). Measurements were performed in a lead chamber protecting the device against a high-energy natural background of 1999. A «softer» background typical for 1986 was imitated by placing - in different parts of the chamber and on different height - vessels filled with peas contaminated by ^{137}Cs and ^{134}Cs with a specific activity equal to 12.4 nCi kg^{-1} and 0.26 nCi kg^{-1}, respectively. The measurements were performed using SRP-68-01 device with and without collimator. Cs radionuclide content in the body of the person tested was lower than 10 nCi, what corresponds to counting rates of SRP-68-01 with and without collimator: less than 0.05 and 0.15 pulse s^{-1}, respectively. The minimally detectable counting rate for time of measurement equal to 100 s and provided error of measurement equal to 20%, made 0.69 pulse s^{-1}. The background signal was measured in the same geometry as for k_1 measurements, i.e. the detector or collimator edge was put close to the neck and lower part of the abdomen. The measurements were repeated 9 times in both cases when using a collimator, and 6 times without collimator. Device background was subtracted from the results of measurements as not related with gamma-radiation in the chamber.

The results obtained are given in Table 8.29.4.

Table 8.29.4. – Factors of shielding by human body of scattered γ-radiation

Collimator	Counting rate in the absence of the patient, pulse s^{-1}	Counting rate on thyroid level, pulse s^{-1}	Counting rate on abdomen level, pulse s^{-1}	k_2 on thyroid level	k_2 on abdomen level
Without	4.90±0.11	4.65±0.13	4.51±0.09	0.95±0.03	0.92±0.03
With	1.22±0.09	1.15±0.09	1.11±0.07	0.94±0.07	0.92±0.10

The result obtained of k_2 estimate coincides well with literature data. In our calculations it was assumed that the shielding factors k_2 in measurements on thyroid and abdomen levels do not differ and are equal to 1 for children aged 0 to7 years, and 0.95 for children aged 8 to 18 years. As regards distribution of these factors, it is assumed to be triangular, asymmetrical for children aged 0 to7 years and symmetrical for children aged 0 to18 years.

We consider that additional model measurements are necessary in order to estimate age relationship between the shielding factor k_2 under conditions of scattered γ-radiation from radiocaesium.

8.29.2.4. Relationship between the level of superficial contamination and radiocaesium content in the body (parameter $r(t)$), and its deformation under the influence of washing (k_w)

As concerns the values $r(t)$, as well as changes in this relationship under the influence of body washing, we have no own data. We are grateful to Alexander Shinkarev who provided us with materials from his scientific thesis [5], containing the results of measurements which we have used for an approximate estimate of $r(t)$ and k_w.

In order to estimate the efficacy of washing process (modification of r factor by k_w factor), with the purpose of decreasing superficial contamination (and, therefore, decreasing N_{sc} counting), we use the model of observations previously described (2) and data [5]. According to [5], as a result of washing of patients, the counting measured in the field of abdomen (with background subtracted) decreased by 2.5 times for the group with a trustworthy effect of washing. Using the denotations of the models (2) and (4), the ratio of count rate from abdomen measurements before and after washing can be shown as follows:

$$\frac{(N_{ab}^{Cs}+N_{sc})}{(N_{ab}^{Cs}+k_w N_{sc})}=\frac{(N_{ab}^{Cs}+r N_{ab}^{Cs})}{(N_{ab}^{Cs}+k_w r N_{ab}^{Cs})}=\frac{(1+r)}{(1+k_w r)}. \tag{11}$$

Taking into account the group of patients for which washing has not trustworthily changed counting on abdomen level, the weighed average for the gathered sample was estimated as a decrease by 1.94 time. Therefore, $k_w \cong 0.5$.

For thyroid region the averaged weighed decrease in counting made 1.5 [5].

To estimate the ratio $r(t)$ we have used experimental data from [5] shown on figure 8.29.1. Experimental values for r (based on data shown on figure 8.29.1) were calculated using assessments of the factor of abdomen and thyroid count rate reduction following the washing procedures for the whole group of patients in [5] (reduction as low as 1.94 times and 1.5 times respectively). Besides, it was also considered that, based on the denotations of our models (1) and (2), the experimental ratio of □ab/□th for washed patients looks as follows:

$$\frac{P_{ab}}{P_{th}}=d_1=\frac{(N_{ab}-k_2 N_{bg})\,1.5}{1.94\,(N_{th}-k_2 N_{bg})}=\frac{(N_{ab}^{Cs}+N_{sc})\,1.5}{1.94\,(N_{th}^{J}+N_{th}^{Cs}+N_{sc})} \tag{12}$$

The model value of d_2 presented in denotations of models (1) and (2) is as follows

$$d_2=\frac{N_{ab}^{Cs}}{N_{th}^{J}}. \tag{13}$$

Using the ratios (3) and (4) and presenting $w_1=\frac{1.5}{1.94}$ one obtains the following equation to calculate the experimental r values based on the data of figure 8.29.1:

$$r=\frac{\left(\frac{d_1}{d_2}+k_1\,d_1-w_1\right)}{(w_1-d_1)}, \tag{14}$$

where

d_1, d_2 = Defined in caption to figure 8.29.1 ;

w_1= (1.5/1.94) - factor of alterations in d_1 value following the washing procedure. Estimates 1.5 and 1.94 are obtained considering the group of patients from [5], who had almost the same values of N_{ab} and N_{th} after the washing procedure.

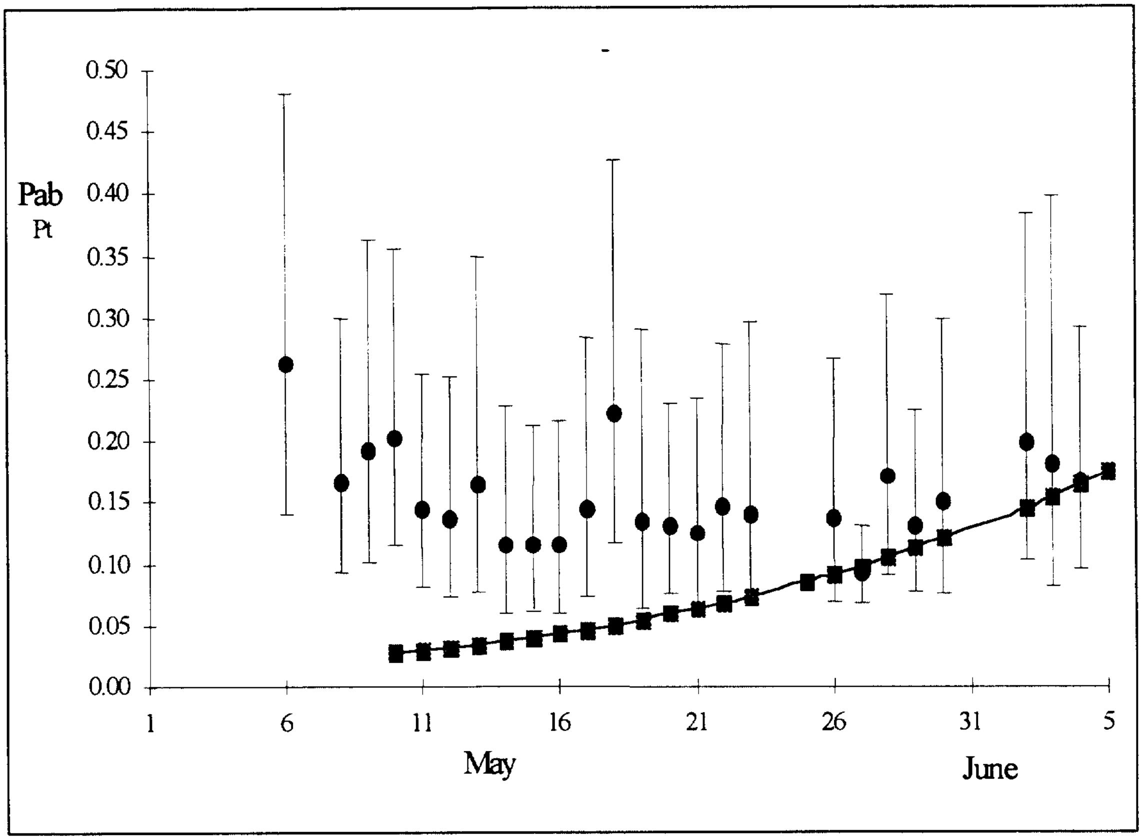

Fig. 8.29.1. Relationship between median values of P_{ab} / P_{th} ratio (minus background at the place of measurement) and the date of examination in Belarus hospitals in rural population of Gomel region after washing [5].

● - Experimental data: □ab / □th – The ratio of the measured exposure rate over the abdomen (with background substracted) to the measured exposure rate over the thyroid (with background substracted) - hereinafter d_1 .

■ -Theoretical calculation using the model for the ratio of exposure rate from radio ceasium incorporated into the body to ^{131}I in thyroid - hereinafter d_2 .

The daily median values of r observed are represented on Fig. 8.29.2. One may note a steady tendency to decreasing of r with increasing time, what correlates well with dosimetric considerations as to the behavior of r: with increasing time the contribution of incorporated radionuclides in the body is increasing, while superficial contamination is decreasing. The relationship between r and t, day after the accident, is adjusted by an exponential model given on Fig. 8.29.2, and is given in Table 8.29.5.

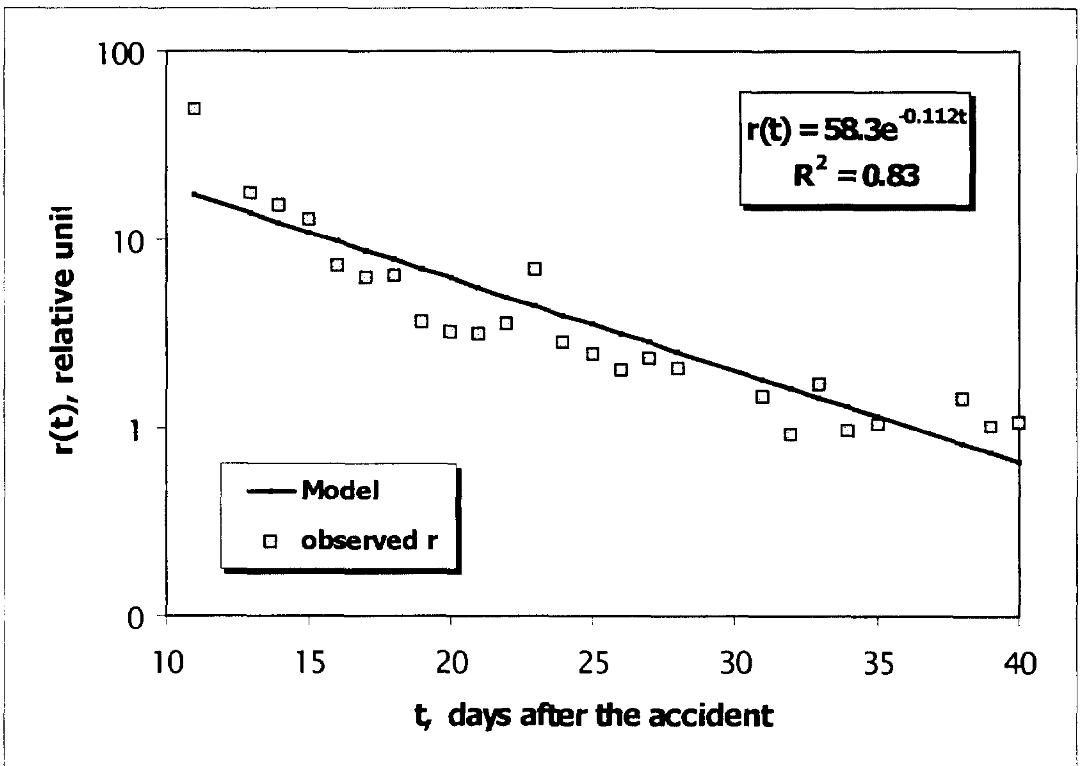

Fig. 8.29.2. Experimental and model values of $r(t)$ factor

Table 8.29.5. Numerical values of experimental and model of $r(t)$

Data	t, days	r	Model
6-May-86	11	49.57	17.01
8-May-86	13	17.74	13.59
9-May-86	14	15.23	12.15
10-May-86	15	12.89	10.87
11-May-86	16	7.20	9.71
12-May-86	17	6.33	8.69
13-May-86	18	6.41	7.76
14-May-86	19	3.68	6.94
15-May-86	20	3.24	6.21
16-May-86	21	3.14	5.55
17-May-86	22	3.61	4.96
18-May-86	23	6.88	4.44
19-May-86	24	2.85	3.97
20-May-86	25	2.47	3.55
21-May-86	26	2.03	3.17
22-May-86	27	2.36	2.83
23-May-86	28	2.07	2.53
26-May-86	31	1.49	1.81
27-May-86	32	0.93	1.62
28-May-86	33	1.70	1.45
29-May-86	34	0.98	1.29
30-May-86	35	1.05	1.16
2-Jun-86	38	1.44	0.83
3-Jun-86	39	1.03	0.74
4-Jun-86	40	1.08	0.66

In calculations of activity the model representation of $r(t)$ obtained has been used:

$$r(t)=58.3\,e^{-0.112(t_m-t_0)} \tag{15}$$

where

$t_m=$ Date of measurement
$t_0=$ 26.04.86

We assume that (15) gives the dependence of median value of $r(t)$ as a function of time; distribution of individual values of r for a fixed t is lognormal with GSD=2.

As it follows from the calculations performed, the value of $r(t)$ is decreasing twice after washing, on an average. Therefore, taking into account the assumption (5) :

$$r(t,w)=\left\{\begin{array}{l} r(t), \text{ in case of answer "no" to the question about washing} \\ 0.5\, r(t), \text{ in case of answer "yes" to the question about washing} \\ 0.75\, r(t), \text{ in case of answer "do not know" to the question about washing} \end{array}\right\} \quad (16)$$

where

w= Information on washing before counting

For the factor of washing which modifies the estimated value of $r(t)$ according to the expression (16), a triangular distribution is supposed, with a minimal value 0.1 and maximal value 1.

8.29.2.5. Values used and assumptions on distributions of parameters K_s, K_{ov}, and K_m, of the formula for calculating activity and uncertainty.

Age relationship K_{ov} is determined by the data of measurements using SRP-68-01 on an age thyroid phantom [4] and is described by the function:

$$K_{ov}(a)=\frac{1}{0.9174 - 0.000011a^2 - 0.000397a} \quad (17)$$

where

a - Age of measured person, years.

For the parameter K_{ov} a triangular distribution is supposed, with a mode equal to the age-related value K_{ov} , and maximal and minimal values differing from the mode by 6% [4].

The age dependence K_m is determined by the data of measurements using SRP- 68-01 on an age thyroid phantom [4]. K_m is equal to 1.1 for children aged 0 to 6 years and to 1.0 for persons aged from 7 and over. For the parameter K_m a triangular distribution is supposed, with a mode equal to the age-related value, and maximal and minimal values differing from the mode by 15% [4].

The value of calibration factor of SRP-68-01 according to the control source, K_s, is estimated as an average for a sample of factors for devices that have been used in Ukraine, and is equal to 4.2 10^{-3} μCi h μR^{-1}. A lognormal distribution is supposed for this factor, with parameters GM=3.8

10^{-3} and GSD=1 .23. This distribution illustrates the worst case, i.e. when a specific SRP-68-01 device, which was used in measurements, lacks the results of calibration to control source. If calibration was conducted during the measurement process, K_s distribution is assumed normal with average of 4.2 10^{-3} μCi h $\mu R^{-1}$and veriance of 0.2 (veriance is estimated as average veriance over all results of calibration for the specific devices).

Fixed values in measurements using SRP-68-01 device, according to the scenarios proposed, are represented by the gamma-exposure rates N_{th} , N_{ab}, N_{bg} (μR h^{-1}), which are linked with estimation of intensity of Poisson number of decays in pulses s^{-1} (n/t) by the following relation:

$$N_{th}=\frac{\frac{n}{t}}{3.226} \tag{18}$$

where 3.226 is the factor of conversion from μR h^{-1} into pulses s^{-1} in measurements using SRP-68-01 (pulse h μR^{-1} s^{-1}).

For the parameters ***Measured exposure rates*** $(\mu R\ h^{-1})$ from Table 8.29.1. (N_{th} , N_{ab}, N_{bg}), a normal distribution is supposed, whose average is represented in proposed scenarios.

Variances of these parameters are derived from the assumption on Poisson character of distribution of the number of pulses registered when counting on thyroid level: n_{th}, on abdomen level: n_{ab} , and when measuring background: n_{bg}:

$$n \cong \text{Poisson}(\lambda t), \quad \lambda=\frac{n}{t}$$

It follows from this the variance of N:

$$\sigma_N^2=\frac{\lambda t}{t^2\,3.226^2}=\frac{n}{t^2\,3.226^2}=\frac{N}{t\,3.226} \tag{19}$$

Time of measurement was automatically established in the process of measurement using SRP-68-01, and was equal to 5 s.

SRP-68-01 device is a pointer-type instrument with five scales of range of measurement. Counting of results of measurement is accompanied by a reading error, K_{er}, which is an additive one and is regularly distributed in an interval which is determined by the multiplying factor of the scale of device. The estimates of maximal absolute and relative reading errors for each scale are given in Table 8.29.6.

Table 8.29.6. Reading errors for SRP-68-01 devices

Range, μR per h	Multiplying factor, μR per h	Maximal absolute reading error, μR per h
10-30	0.5	0.25
30-100	2	1
100-300	5	2.5
300-1000	20	10
1000-3000	50	25

Taking into account the reading error, the formula for calculating activity when modelling uncertainties of the estimate obtained has the following form:

$$A\ (kBq) = 37\, K_s \frac{K_{ov}(a)}{K_m(a)} N_{th}^{J} =$$

$$= 37\, K_s \frac{K_{ov}(a)}{K_m(a)} \left\{ (N_{th} + K_{er\_th}) - (N_{ab} + K_{er\_ab}) \frac{[k_1 + r(t,w)]}{[r(t,w)+1]} - (N_{bg} + K_{er\_bg}) \frac{k_2(a)\,(1-k_1)}{[r(t,w)+1]} \right\} \quad (20)$$

where

K_{er_th}= Additive reading error when measuring N_{th}, μR h^{-1};
K_{er_ab}= Additive reading error when measuring N_{ab}, μR h^{-1};
K_{er_bg}= Additive reading error when measuring N_{bg}, μR h^{-1};
The rest of parameters have been previously determined.

As a numerical procedure of modelling of distribution of individual errors, Monte-Carlo method of modelling was used, namely, the generation of distribution of errors on the basis of random samples (5,000 samples) from multidimensional distribution of the vector of parameters of the model (simple random sampling process). Probabilistic features of each of these parameters of the model (20) are gathered in Table 8.29.7.

Table 8.29.7 Supposed distribution of parameters for calculating uncertainties of individual activities

Parameter	Distribution	Age, y	μ (σ) or mean (SD) or mode	Minimum	Maximum
$k_2(age)$	Triangular	0-7 8-18	1[a] 0.95[a]	0.95 0.90	1 1
k_1	Lognormal		-0.211 (0.038)[b]		
r	Lognormal		ln(eq.(15)) (0.693)[b]		
k_w	Triangular		eq.(16)	0.1	1
K_{ov}	Triangular		Eq(17)[a]	Mode-0.06*Mode	Mode+0.06*Mode
K_m	Triangular	0-6 7-18	1.1[a] 1.0[a]	Mode-0.15*Mode Mode-0.15*Mode	Mode+0.15*Mode Mode-0.15*Mode
K_s	Lognormal (the worst case)□ Normal (the best case)□□		$3.8*10^{-3}$ (1.23)[b] $4.2*10^{-3}$ (0.2)□		
N_{th}	Normal		Table 8.29.1 (Eq.19)[c]		
N_{ab}	Normal		Table 8.29.1 (Eq.19)[c]		
N_b	Normal		Table 8.29.1 (Eq.19)[c]		
$K_{er\ th}$	Uniform		0	[d]	[d]
$K_{er\ ab}$	Uniform		0	[d]	[d]
$K_{er\ b}$	Uniform		0	[d]	[d]

[a] the figures represent the mode values for triangular distributions.

[b] μ and σ represent the mean and standard deviations, respectively, for logarithmic converted data.

[c] Mean and standard deviations, respectively, for normally distributed date.

[d] Maximal and minimal values are determined as "+ maximal absolute error" and "– maximal absolute error" for the corresponding scale range (Table 8.29.6).

[e] the worst case - when a specific SRP-68-01 device, which was used in the measurements lacks the results of calibration to control source.

[ee] the best case - when a specific SRP-68-01 device, which was used in measurements, was calibrated with a referance source during the measurements.

8.29.2.6. Results of thyroid activity estimate

The estimates obtained and their uncertainties are gathered in Table 8.29.8. The Table gives the estimates for counting rate from ^{131}I in thyroid (N^{I}_{th}), ^{131}I activity in thyroid (A_{th}), and the parameters of distribution of activity estimates which were obtained vie Monte Carlo simulation assuming distributions for parameters of model (20) as given in Table 8.29.7. Parameters of distribution of activity estimates (uncertainties of the estimates of activity) were calculated for two cases of SRP-68-01 calibration (the worst case and the best case concerning the results of calibration of a specific device with a control source).

Table 8.29.8 Result of estimation of ^{131}I activity in thyroid on reference day

			Parameters of distribution obtained with Monte Carlo simulation									
Subject	N^{J}_{th}, μR/h	A_{th}, kBq	The worst case[a]					The best case[b]				
			A_{th}, average	A_{th}, GM	ln(GSD)	95%CI		A_{th}, average	A_{th}, GM	ln(GSD)	95%CI	
						A_{th}, Min	A_{th} Max				A_{th}, Min	A_{th} Max
A	2466.2	**380.8**	375.9	366.5	0.225	234.8	578.2	366.9	365.3	0.095	303.5	437.0
B	535.5	**91.2**	89.8	87.6	0.222	56.5	135.9	88.0	87.5	0.099	71.9	106.4
C	197.5	**30.4**	30.1	29.3	0.231	18.5	45.7	29.4	29.2	0.124	22.9	37.4
D	1483.4	**252.9**	248.5	242.4	0.224	156.3	373.5	243.7	242.5	0.097	200.8	292.0
E	2261.9	**387.0**	378.4	369.3	0.221	241.0	567.6	372.3	370.6	0.096	307.6	445.0
V	194.1	**29.9**	29.7	28.8	0.243	17.9	46.1	29.1	28.8	0.135	22.1	37.3
W	2121.5	**326.9**	321.1	313.4	0.220	203.5	484.0	313.3	311.9	0.093	260.5	373.8
X	105.2	**16.2**	16.2	15.7	0.264	9.2	26.0	15.9	15.7	0.174	11.0	21.7
Y	358.1	**55.3**	54.6	53.3	0.222	34.0	81.8	53.3	53.0	0.099	43.8	64.2
Z	74.3	**12.6**	12.6	12.2	0.235	7.6	19.3	12.3	12.2	0.125	9.6	15.6

[a] **The worst case** - the lack of the results of calibration for the specific SRP-68-01 device, which was used in measurements

[b] **The best case** -specific SRP-68-01 device was calibrated during the measurements

8.29.3 Thyroid exposure dose estimates

8.29.3.1. Model of intake function and current content of ^{131}I in thyroid gland

In order to calculate the doses for a known value of activity ($A(t_{mi})=50$ kBq, $i\in[1,..,10]$), measured for each hypothetical subject on a day defined as reference day from Table 8.29.1., it has been used models of intake function and current content of ^{131}I in thyroid gland, which have been described in the report for the first quarter 1999-2000. A formal description of models for a subject i in the form of a system of differential equations of first order, supplemented with ordinary equations, is given below:

$$V_i(t_f)=\frac{P_i(t_f)}{V_g},\ \text{for } t_f\in\{0,\ldots 100\},\quad t\in[0-\tau_s,\ ,100], \tag{21}$$

Air (21)

$$dy_{1i}(t)/dt=-\lambda_g\, y_{1i}(t)+b_1 V_i(t_f),\quad y_{1i}(t\le 0)=0; \tag{22}$$

Pasture grass, leafy vegetables (22)

$$dy^c_{2i}(t)/dt=-\lambda^c_m\, y^c_{2i}(t)+b^c_2\, y_{1i},\quad y^c_{2i}(t\le t_{pi})=0, \tag{23}$$

Backyard cow's milk (23)

$$y^s_{2i}(t)=\min\left\{TPL_m;\qquad y^c_{2i}(t-\tau_s)e^{-\lambda_r(t-\tau_s)}\right\},\quad y^s_{2i}(t\le t_{pi})=0; \tag{24}$$

$$TPL_m(t_l)=\begin{cases}\infty, & t<t_l\\ 3.7\ \text{kBq}, & t\ge t_l\end{cases}$$

Milk purchased through trading networks (24)

$$dy^g_{2i}(t)/dt=-\lambda^g_m\, y^g_{2i}(t)+b^g_2\, y_{1i},\quad y^g_{2i}(t\le t_{pi})=0, \tag{25}$$

Goat's milk (25)

$$F_i(t,age)=K_{bi}(t)\, q_{0i}\, w_{Th}\Big\{ w_{inh}\, r_1(age)\, V_i(t_f)+ \\ + w_{ing}\left[r^{lv}_i(t)\, y_{1i}(t)+r^c_i(t)\, y^c_{2i}(t)+r^s_i(t)\, y^s_{2i}(t)+r^g_i(t)\, y^g_{2i}(t)\right]\Big\} \tag{26}$$

Thyroid intake function (26)

$$K_{bi}(t)=\begin{cases}1.0, & t<t^b_k\\ 0.1, & t=t^b_k\\ 0.0, & t=(t^b_k+1),\ldots,\ldots(t^b_k+n^b_k);\quad k^b=k^b_i\\ 0.5, & t=t^b_k+n^b_k+1\\ 1.0, & t\ge t^b_k+n^b_k+2\end{cases} \tag{27}$$

Individual function of thyroid blockade by stable iodine (27)

$$r^{lv}(t,i)=\begin{cases} r_1^{lv}, & 0\le t< t_1^{lv} \\ \vdots & \\ r_{ki-1}^{lv}, & t_{ki-1}^{lv}\le t< t_{ki}^{lv} \\ r_{ki}^{lv}, & t\ge t_{ki}^{lv} \end{cases}$$	Individual function of leafy vegetables consumption	(28)
$$r_i^{c}(t)=\begin{cases} r_1^{c}, & 0\le t< t_1^{c} \\ \vdots & \\ r_{ki-1}^{c}, & t_{ki-1}^{c}\le t< t_{ki}^{c} \\ r_{ki}^{c}, & t\ge t_{ki}^{c} \end{cases}$$	Individual function of consumption of backyard cow's milk	(29)
$$r_i^{s}(t)=\begin{cases} r_1^{s}, & 0\le t< t_1^{s} \\ \vdots & \\ r_{ki-1}^{s}, & t_{ki-1}^{s}\le t< t_{ki}^{s} \\ r_{ki}^{s}, & t\ge t_{ki}^{s} \end{cases}$$	Individual function of consumption of milk purchased through trading networks	(30)
$$r_i^{g}(t)=\begin{cases} r_1^{g}, & 0\le t< t_1^{g} \\ \vdots & \\ r_{ki-1}^{g}, & t_{ki-1}^{g}\le t< t_{ki}^{g} \\ r_{ki}^{g}, & t\ge t_{ki}^{g} \end{cases}$$	Individual function of goat's milk consumption	(31)
$$q_{0i}=\frac{A_i^*}{A_i(t_{mi}+\tau^m)}=\frac{50}{A_i(t_{mi}+\tau^m)}$$	Parameter scaling the individual function of current content of ^{131}I by the result of measurement	(32)
$$dA_i(t)/dt=-\lambda_{th}(age)\,A_i(t)+K_i^{rel}(t)\,F_i(t,age),\quad A_i(t_0)=0$$	Individual function of the thyroidal contents of ^{131}I	(33)
$$K_i^{rel}(t)=\begin{cases} 1, & t\le t_i^{rel}+\tau^{rel} \\ 0, & t> t_i^{rel}+\tau^{rel} \end{cases}$$	Function of relocation to non-contaminated areas	(34)

where

$V_i(t_f)$ = Mean specific activity of ^{131}I in the air on fallout days (kBq m^{-3});

t_f = Fallout days, calculated from data in Table 8.29.1 as ***Date(s) of ^{131}I deposition*** –26.04.86;

V_g= Deposition velocity (m d^{-1});

$P_i(t_f)$= ***^{131}I deposition*** from Table 8.29.1 (kBq m^{-2} d^{-1});

$y_{1i}(t)$= Function of specific activity of ^{131}I in pasture grass. A similar function is assumed for leafy vegetables (kBq kg^{-1});

λ_g= Effective rate of ^{131}I activity decrease in pasture grass; similary assumed for leafy vegetables (d^{-1});

$y_{2i}^{c}(t)$= Function of specific activity of ^{131}I in backyard cow's milk (kBq l^{-1});

$y_{2i}^{s}(t)$= Function of specific activity of ^{131}I in milk purchased through trading networks (kBq l^{-1});

$y_{2i}^{g}(t)$= Function of specific activity of ^{131}I in goat's milk (kBq l^{-1});

t_{pi}= Day of beginning of dairy animal pasturing in the scenario of the *i*-th subject; it is calculated from the data of Table 8.29.1 as (***Date dairy animals on pasture in area***–26.04.86);

b_1= Air-to-grass efficiency transfer rate (m^3 kg^{-1} d^{-1});

λ_m^c= Effective rate of ^{131}I activity decrease in cow's milk (d^{-1});

λ_m^g= Effective rate of ^{131}I activity decrease in goat's milk (d^{-1});

b_2^c= Grass-to-cow's-milk efficiency transfer rate (kg l^{-1} d^{-1});

b_2^g= Grass-to-goat's-milk efficiency transfer rate (kg l^{-1} d^{-1});

TPL_m= Temporary permissible level of ^{131}I content in cow's milk, which has been introduced with the Order □ 4404-86 issued on 6.05.86 for milk purchased through trading networks of former USSR, and equal to 3.7 kBq l^{-1} [12];

t_l= Day of introduction of temporary permissible level (assumed the introdaction on the next day after the Order □4404-86, i.e. May 7, 1986; calculated as (7.05.86-26.04.86));

λ_r= Rate of radioactive decay of ^{131}I (d^{-1});

τ_s= Time elapsed between production and ingestion of milk purchased through trading networks, days;

w_{inh}= Absorption of iodine by blood when incorporated through inhalation (dimensionless);

w_{ing}= Absorption of iodine by blood when incorporated in foodstuffs (dimensionless);

w_{Th}= Fractional uptake of iodine by thyroid after its entry into blood (dimensionless);

$r_1(age)$= Age-dependent ventilation rate (m^3 d^{-1});

$r_i^{lv}(t)$= Step function of individual consumption of leafy vegetables by a subject *i* (kg d^{-1});

r_{ki}^{lv}= Leafy vegetable consumption rate for k-th period of unchanged consumption (take in Table 8.29.1 ***Leafy vegetable consumption rate/new rate*** (kg d^{-1}));

t_{ki}^{lv}= Day of beginning of k-th period of unchanged consumption of leafy vegetables; calculated from Table 8.29.1 as (***Change in Leafy vegetable consumption rate? Date* – 26.04.86**);

n_{ki}^{lv}= Duration of k-th period of unchanged consumption of leafy vegetables; calculated from Table 8.29.1 (*d*);

k_{i}^{lv}= Number of periods of unchanged consumption of leafy vegetables for a subject i ; take in Table 8.29.1 (dimensionless);

$r_i^{\bar{n}}(t)$,$r_i^{s}(t)$, $r_i^{g}(t)$= Step function of individual consumption of backyard cow's milk (^{c})/ milk purchased through trading networks (^{s})/goat's milk (^{g}) (l d^{-1});

r_{ki}^{c} ,r_{ki}^{s} , r_{ki}^{g}= Consumption rate for backyard cow's milk (^{c})/ milk purchased through trading networks (^{s})/goat's milk (^{g}) in k-th period of unchanged consumption; take in Table 8.29.1 ***Milk consumption rate/new rate*** (l d^{-1});

t_{ki}^{c} , t_{ki}^{s} , t_{ki}^{g}= Day of beginning of k-th period of unchanged consumption of backyard cow's milk (^{c})/ milk purchased through trading networks (^{s})/goat's milk (^{g}); calculated from Table 8.29.1 as (***Change in Milk consumption rate? Date* – 26.04.86**);

n_{ki}^{c} , n_{ki}^{s} , n_{ki}^{g}= Duration of k-th period of unchanged consumption of backyard cow's milk (^{c})/ milk purchased through trading networks (^{s})/goat's milk (^{g}); calculated from Table 8.29.1 (*d);*

k_{ki}^{c} , k_{ki}^{s} , k_{ki}^{g}= Number of periods of unchanged consumption of backyard cow's milk (^{c})/ milk purchased through trading networks (^{s})/goat's milk (^{g})for a subject i ; take in Table 8.29.1 (dimensionless);

$F_i(t,age)$= Age-dependent ^{131}I thyroid intake function for the i-th subject (kBq d^{-1});

K_{bi}= Step function of thyroid's blockade with stable iodine for the i-th subject;

t_{ki}^{b}= Day of beginning of k-th period of stable iodine consumption for the i-th subject (calculated from Table 8.29.1 ***Took stable iodine tablets?*** as (***Start date*** –26.04.86));

n_{ki}^{b}= Duration of k-th period of stable iodine consumption for the i-th subject (calculated from Table 8.29.1 ***Took stable iodine tablets?*** as (***End date -Start date***));

k_{i}^{b}= Number of periods of stable iodine consumption for the i-th subject (period of consumption: one or several days without interruption), according to Table 8.29.1;

q_{0i} = Scaling parameter for the model function of ^{131}I content in thyroid of i-th subject, obtained from the results of measurement according to (32) (dimensionless);

$A_i(t)$ = Function of ^{131}I content in thyroid for the i-th cohort member (kBq);

A_i^* = Result of thyroid activity measurements (kBq);

t_{mi} = Day of thyroid activity measurement after t_0 for the i-th subject (calculated from Table 8.29.1 as ***(Date of measurement* – 26.04.86)**);

τ^{m} = Correction for a delay taking into account average time of the measurement assumed to be equal to 0.5 d, i.e. measurement is supposed to be performed at 12 a.m. (d);

t_i^{rel} = Day of relocation to non-contaminated areas after t_0 for the i-th subject (calculated from Table 8.29.1 as ***(Was subject relocated? When, Where* – 26.04.86)**);

τ^{rel} = Correction for a delay in the settlement during evacuation or departure; assumed to be equal to 0.75 d (departure at 6 p.m.) (d);

$\lambda_{th}(age)$= Rate constant corresponding to age-dependent effective half-life of ^{131}I in the thyroid (d^{-1}), taken as an approximation [1] and given in Table 8.26.1;

$K_i^{rel}(t)$= Factor for taking into account the influence of relocation to non-contaminated areas (dimensionless).

8.29.3.2. Calculation of thyroid exposure doses

The following equation was used for thyroid exposure dose calculation:

$$D_i(mGy)=\frac{10^3\ 84600\ 1.6\ 10^{-13}}{10^{-6}}\ \frac{E_{th}^{131}}{m_{th}(age)}\int_0^{200} A_i(t)\,dt=\frac{13.82\,E_{th}^{131}}{m_{th}(age)}\int_0^{200} A_i(t)\,dt \qquad (35)$$

where

E_{th}^{131} = Mean total energy absorbed per 1 decay of ^{131}I in thyroid gland (MeV per decay);

10^3 Number of decays per s in 1 kBq;

86400 Number of s per d;

$1.6\ 10^{-13}$ Number of J per MeV;

10^{-6} 10^{-6} J per g – energy equivalent of 1 mGy;

$m_{th}(age)$ = Age-dependent thyroid mass, g;

200 Integration limit for numerical integration for t in days.

8.29.3.3. Values of models' parameters and assumptions about their distributions

The ^{131}I deposition velocity on soil, V_g, is considered as maximal deposition velocity on soil or on fully developed grass foliage; the value 7 mm s^{-1} = 604.8 m d^{-1} from [6] is used. A lognormal distribution with parameters GM=604.8 m d^{-1} , and GSD=2 is being supposed for it.

The parameter b_1 is designed by the expression from [7]:

$$b_1 = \frac{v_{gg}}{Y_g} \tag{36}$$

where

v_{gg} = Deposition velocity on pasture grass (m d^{-1});

Y_g = Yield of grass (kg m^{-2}) at the time of deposition.

The value of Y_g, being supposed in the model, has been taken in [7] for the period 1.05 - 15.05 as 1.5 kg m^{-2}. A lognormal distribution with parameters GM=1.5 kg m^{-2} , GSD=1.2 is supposed for it (Table 8.29.10).

According to [7], the deposition velocity on pasture grass (leafy vegetables) may be expressed as follows:

$$v_{gg} = V_g\,[1 - \exp(-k\,Y_g)] \tag{37}$$

where

V_g = Maximal deposition velocity (m d^{-1}) for soil or fully developed grass foliage;

k = Normalizing factor for dry depositions (1 m^2 kg^{-1}). It is supposed to be a constant.

The following formula is being used for the parameter λ_g:

$$\lambda_g = \frac{\ln(2)}{T_w} + \frac{\ln(2)}{T_g} + \frac{\ln(2)}{T_r} \tag{38}$$

where

T_w= Weathering half-life for grass (d);

T_g= Half-life due to growth dilution in May (d);

T_r= Half-life due to ^{131}I radiological decay, 8.04 d.

The following formulae are used for the parameters λ_m^c and λ_m^g :

$$\lambda_m^c = \frac{\ln(2)}{T_b^c} + \frac{\ln(2)}{T_r} \quad \text{and} \quad \lambda_m^g = \frac{\ln(2)}{T_b^g} + \frac{\ln(2)}{T_r} \tag{39}$$

where

T_b^c = Half-life of biological transfer of iodine into cow's milk (d);

T_b^g = Half-life of biological transfer of iodine into goat's milk (d).

For the parameter $\lambda_{Th}(age)$ the following formula is being used:

$$\lambda_{th}(age) = \frac{\ln(2)}{T_b(age)} + \frac{\ln(2)}{T_r} \tag{40}$$

where

$T_b(age)$= Age-dependent half-life of biological elimination of iodine from thyroid gland (d) (Table 8.29.9).

The assumptions, used for modelling, about statistical features of the parameters T_w, T_g, [7], T_b^c, and T_b^g [7,9], are given in Table 8.29.10.

For the parameter $T_b(age)$ a lognormal distribution is to be supposed, with GM determined by Table 8.29.9, which have been obtained by linear interpolation of values from [10]. The variance of $T_b(age)$ is derived in assuming a factor of variation of logarithms T_b, identical for all ages and equal to 10% (Table 8.29.10).

The values of parameter t_{pi} have been taken in scenarios (Table 8.29.1) and are assumed to be constants, except scenarios for subjects E and X who do not remember the exact date of beginning of dairy animals' pasturing. For these a uniform distribution of t_{pi} is being supposed, with parameters (min and max) indicated in Table 8.29.1 as a possible interval of dates of pasturing (Table 8.29.10).

Efficacy of ^{131}I transfer from fresh green fodder into cow's milk b_2^c is described using a quantity of fodder being eaten by a cow per day $I_{g,c}$, , equilibrium transfer factor TF_m^c , and rate of biological transfer of iodine into cow's milk λ_b^c :

$$b_2^c = TF_m^c \, I_{g,c} \, \lambda_b^c = TF_m^c \, I_{g,c} \, \frac{\ln(2)}{T_b^c} \qquad (41)$$

where

$I_{g,c}$ = Consumption of pasture grass by a cow (kg d^{-1});

TF_m^c = Transfer factor for cow's milk (d l^{-1});

λ_b^c = Rate of biological transfer of iodine into cow's milk (d^{-1}).

The value $I_{g,c}$ is supposed to be equal to 50 kg day^{-1} (fresh weight) [9]. Distribution for this parameter is supposed to be uniform with min and max [40; 60] (Table 8.29.10).

The value TF_m^c is supposed to be equal to 4 10^{-3} d l^{-1} [8]; its distribution is supposed to be lognormal with GM=4 10^{-3} d l^{-1} and GSD=2.1 (Table 8.29.10).

Efficacy of ^{131}I transfer from fresh green fodder into goat's milk b_2^g is described using a quantity of fodder being eaten by a goat per day $I_{g,g}$, equilibrium transfer factor TF_m^g , and rate of biological transfer of iodine into of goat's milk λ_b^g :

$$b_2^g = TF_m^g \, I_{g,g} \, \lambda_b^g = TF_m^g \, I_{g,g} \frac{\ln(2)}{T_b^g} \tag{42}$$

where

$I_{g,g}$ = Consumption of pasture grass by a goat (kg d^{-1});
TF_m^g = Transfer factor for goat's milk (d l^{-1});
λ_b^g = Rate of biological transfer of iodine into goat's milk (d^{-1}).

The value $I_{g,g}$ is assumed to be equal to 13 kg d^{-1} (fresh weight) [7]. Distribution for this parameter is supposed to be uniform with min and max [10; 16] (Table 8.29.10).

The value TF_m^g is assumed to be equal to 2.2 10^{-1} d l^{-1} [8]; its distribution is supposed to be lognormal with GM=0.22 d l^{-1} and GSD=2.5 (Table 8.29.10).

The parameter τ_s is assumed to be equal to 1.75 d (mode); its distribution is supposed to be triangular with min and max [1.5; 2.5] (Table 8.29.10).

The parameter τ^{rel} is assumed to be equal to 0.75 d (mode); its distribution is supposed to be triangular with min and max [0.25 ; 0.85] (Table 8.29.10).

The parameter τ^{m} is assumed to be equal to 0.5 d (mode); its distribution is supposed to be triangular with min and max [0.3 ; 0.8] (Table 8.29.10).

The values for parameters of fractions of iodine absorption by blood when inhalated and ingested, w_{ing}, and w_{inh}, fractions of iodine uptake by thyroid from blood, w_{th} , used in the model, have been taken in [10]. The parameters w_{ing}, and w_{inh} are supposed to be constants (Table 8.29.10). For the parameter w_{th} a triangular distribution is being supposed, with min and max [0.17 ; 0.5], and mode equals to 0.3 (Table 8.29.10).

The values of age-dependent ventilation rates, $r_1(age)$, are taken as an approximation of levels in [11]. For the parameter $r_1(age)$ a lognormal distribution is being supposed, with GM determined by Table 8.29.9. The veriance of $r_1(age)$ is derived in assuming a standart deviation of logarithms $r_1(age)$, identical for all ages and equal to 0.13 (Table 8.29.10).

For the parameter $m_{th}(age)$ a lognormal distribution is being supposed and average estimates determined by Table 8.29.9 are used. These estimates are obtained by linear interpolation of values from [10]. The variance of $m_{th}(age)$ is derived from the work [4] in assuming a variation factor identical for all ages and equal to 40% for thyroid masses in Ukraine. With this assumption the mean and standart deviation of a log-transformed distribution (μ and δ) are determined as: $\mu=\ln(m_{th}/1.077)$, $\delta=\sqrt{ln(1+0.4^2)}=0.39$ (Table 8.29.10).

The value of parameter E_{th}^{131} is taken from [9] as equal to 0.23 MeV; it is supposed to be triangular, with min and max [0.19; 0.23] (Table 8.29.10).

The values of parameters $P_i(t_f)$, r_{ki}^{lv}, t_{ki}^{lv}, n_{ki}^{lv}, k_{ki}^{lv}, r_{ki}^{c}, t_{ki}^{c}, n_{ki}^{c}, k_{ki}^{c}, r_{ki}^{s}, t_{ki}^{s}, n_{ki}^{s}, k_{ki}^{s}, r_{ki}^{g} t_{ki}^{g}, n_{ki}^{g}, k_{ki}^{g}, t_{mi}, t_i^{rel} are designed by scenarios (Table 8.29.1). And for the parameters characterizing the daily consumption rates (r_{ki}^{lv} , r_{ki}^{c} , r_{ki}^{s} , r_{ki}^{g}) a normal distribution is adopted, with a mode coinciding with values in scenarios and a variation factor equal to 40%. For subjects **B** and **W** one assumes a higher variation factor for these parameters, equal to 60%. The rest of above-mentioned parameters are assumed to be constants.

The value of measured activity A* is designed by scenarios as being identical and equal to 50 □Bq; a lognormal distribution is supposed for A* with GM=50 kBq and δ coinciding with ln(GSD) from the Table 8.29.8 for the corresponding subject.

Table 8.29.9. Values of age-dependent thyroid masses and half-life of biological elimination of iodine from thyroid gland, and respiratory values, being used for dose calculations.

Age, year	m_{th} - Thyroid mass, (g)	T_b - Thyroid biological half-life (d)	r_1- Ventilation rates (m^3 d^{-1})
<0.25	1.45	11.2	2.9
1	1.83	15.0	5.2
2	2.27	17.7	7.0
3	2.78	18.9	8.0
4	3.35	20.2	8.4
5	3.98	23.0	8.7
6	4.68	28.3	9.4
7	5.43	35.5	10.3
8	6.23	43.6	11.5
9	7.09	51.4	12.8
10	8.00	58.0	14.2
11	8.96	62.5	15.5
12	9.97	65.1	16.8
13	11.0	66.4	18.0
14	12.2	66.9	19.1
15	13.3	67.0	20.1
16	14.6	67.3	20.9
17	15.9	68.2	21.6
18	17.4	70.3	22.0
19	19.0	74.1	22.2
20+	20.0	80.0	22.2

Table 8.29.10. Supposed distribution of parameters for calculation of individual dose uncertainties.

Parameter	Distribution	μ (σ) or mean (SD) or mode	Minimum	Maximum
$P_i(t_f)$ – ^{131}I fallout	Const	Table 8.29.1		
V_g- ^{131}I deposition velocity on soil (max deposition velocity) ($m\ d^{-1}$)	Lognormal	Ln(604.8) $(0.693)^b$		
Y_g – grass (leafy vegetables) yield ($kg\ m^{-2}$)	Lognormal	$0.41\ (0.18)^b$		
T_w- weathering half-life for grass (days)	Triangular	25.0^a	15	30
T_g- half-life due to growth dilution in May (days)	Triangular	18.0^a	13.0	23.0
T_b^c- - half-life of biological transfer of iodine into cow's milk (days)	Triangular	0.7^a	0.5	1
T_b^g- - half-life of biological transfer of iodine into goat's milk (days)	Triangular	0.7^a	0.5	1
$T_b(age)$- half-life of biological decontamination of thyroid gland (days)	Lognormal	From-Table 8.29.9 $Ln(T_b)$ $(0.1*\ln(T_b))^b$		
t_{pi} – day of beginning of dairy animal pasture	Const Uniform (subject E) Uniform (subject X)	Table 8.29.1 (30/04-26/04) (2/05-26/04)	 29/04-26/04 28/04-26/04	 1/05-26/04 5/05-26/04
$I_{g,c}$ – feeding rate for cow ($kg\ d^{-1}$)	Uniform	50	40	60
$I_{g,g}$ – feeding rate for goat ($kg\ d^{-1}$)	Uniform	13	10	16
TF_m^c – transfer factor feed cow's milk ($d\ kg^{-1}$)	Lognormal	$-5.52\ (0.74)^b$		
TF_m^g – transfer factor feed goat's milk ($d\ kg^{-1}$)	Lognormal	$-1.51\ (0.92)^b$		

Continuation of Table 8.29.10

Parameter	Distribution	μ (σ) or mean (SD) or mode	Minimum	Maximum
τ_s – interval between production and consumption of milk from shop (d)	Triangular	1.75[a]	1.5	2.5
τ^{m} – correction on time of the measurement (d)	Triangular	0.5[a]	0.3	0.8
τ^{rel} – correction for a delay due to evacuation or departure (d)	Triangular	0.75[a]	0.25	0.85
w_{inh} – fractional uptake by blood while inhalation (dimensionless)	Const	0.63		
w_{ing} – fractional uptake by blood while ingestion (dimensionless)	Const	1		
w_{Th} – fractional uptake by thyroid (dimensionless)	Triangular	0.3	0.17	0.5
m – thyroid mass (g)	Lognormal	From Table 8.29.9. $\ln(m_{th}/1.077)$ (0.39)[b]		
r_1 – respiratory values (m^3 d^{-1})	Lognormal	From Table 8.29.9. $\mathrm{Ln}(r_1)$ (0.13)[b]		
E_{th}^{131} - mean total energy absorbed per 1 decay of ^{131}I in thyroid (MeV per decay)	Triangular	0.23[a]	0.19	0.23
r_{ki}^{lv} , r_{ki}^{c} , r_{ki}^{s} , r_{ki}^{g} – daily comsumption rates for leafy vegetable, cow's milk, cow's milk from shops, goat's milk	Normal	From Table 8.29.1. r (r*0.4)[c] r (r*0.6)[c] for subject **B, W**		
A* - measured activity	Lognormal	Ln(50) (Ln(GSD) from Table 8.29.8.)[b]		

[a] the figures represent the values of mode for triangular distributions;

[b] μ and σ are mean and standard deviation, respectively, for logarithmic-converted data;

[c] mean and standard deviation, respectively, for normal-distributed data.

8.29.3.4. Results of thyroid exposure dose estimation

The results obtained for thyroid exposure dose estimation are given in Table 8.29.11. The parameters of distribution of dose estimate (uncertainties of the estimate of dose) were calculated vie Monte Carlo simulation (1,000 samples) assuming distributions for 26 parameters of models (21)-(42) as given in Table 8.29. 10. Parameters of distribution of dose estimate were calculated for two cases of SRP-68-01 calibration, as it has been done for the activities (see the explanation for the Table 8.29.7 and for the Table 8.29.8) assuming corresponding ln(GSD) from the Table 8.29.8 for measured thyroid activity A*=50 kBq.

Table 8.29.11 Result of estimation of ^{131}I thyroid exposure doses and its uncertainties

Subject	**Point estimate of thyroid dose, mGy**	Parameters of distribution for dose estimate obtained with Monte Carlo simulation									
		The worst case[a]					**The best case**[b]				
		Arithmetic mean dose, mGy	GM dose, mGy	ln(GSD)	95%CI		Arithmetic mean dose, mGy	GM dose, mGy	ln(GSD)	95%CI	
					Low limit, mGy	Upper limit, mGy				Low limit, mGy	Upper limit, mGy
A	**1656.6**	1901.8	1732.0	0.4360	704.1	3965.4	1888.7	1737.0	0.4099	766.2	3918.2
B	**597.7**	690.9	624.6	0.4410	272.1	1497.5	660.8	608.0	0.4079	269.1	1324.7
C	**6330.4**	7730.7	6767.8	0.4963	2688.0	18126.1	7513.3	6823.2	0.4347	3084.3	16311.9
D	**671.0**	753.6	678.2	0.4581	269.9	1751.3	747.2	688.3	0.4036	322.2	1491.3
E	**207.8**	244.7	220.9	0.4564	83.8	536.8	234.9	216.4	0.4034	98.5	488.1
V	**13368.4**	14766.7	12317.0	0.5933	3746.7	37608.9	15259.0	12931.5	0.5698	4500.5	37541.1
W	**1746.7**	1986.8	1816.1	0.4314	706.9	3934.6	1898.1	1754.3	0.3983	810.0	3823.9
X	**2340.7**	2907.6	2578.1	0.4942	933.7	6579.3	2969.7	2689.9	0.4489	1097.9	6274.6
Y	**1563.7**	1779.1	1607.9	0.4504	654.1	3779.2	1765.3	1630.5	0.4005	712.5	3595.5
Z	**909.3**	1039.2	935.7	0.4547	399.4	2333.5	1045.1	958.3	0.4162	409.6	2080.2

[a] **The worst case** - the lack of the results of calibration for the specific SRP-68-01 device, which was used in measurements

[b] **The best case** -specific SRP-68-01 device was calibrated during the measurements

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8.30. OPERATIONS MANUAL FOR-DOSIMETRY: DESCRIPTION OF THE ORGANIZATION AND IMPLEMENTATION OF THE DIRECT THYROID MEASUREMENTS (PROGRESS REPORT)

In September-November 1999 the following tasks have been set in order to prepare the Operation Manual:

- to specify the types of devices having been used for monitoring in Ukraine in 1986 and collect technical documentation for these devices;
- to search the persons who have been involved in thyroid activity measurements.

8.30.1. To specify the types of devices having been used for monitoring in Ukraine in 1986 and collect technical documentation for these devices

It has been performed a search of devices of those types that have been used in thyroid activity measurements in 1986. Table 8.30.1. gives a specified list of types and models of devices with mentioning of institutions where devices of corresponding models are available at present. It is also mentioned in the Table for which device models sets of technical documentation have been found and copied.

It has been established in the process of search that the device mentioned in measurement lists as "Gamma" represents a recalculating unit NC-308 (made at "Gamma" plant, Budapest, Hungary). This device seems to have been used as a recalculating unit for NK-350 device. It has been also established that the device which has been mentioned in measurement lists as PRL and which we had earlier referred, by mistake, to non-spectrometric radiometers, represents a mobile radiometric laboratory intended for spectrometric measurements.

Table 8.30.2 gives an outline of performances of devices for which technical documentation has been found. Tables 8.30.3 – 8.30.10 give serial numbers of the devices having been used, with places and days of measurements.

We consider it necessary to continue search of devices and technical documentation for the following models: DSU 2-1, UR 1-3, UR 3-2, NK-150, PRL.

8.30.2. To search the persons who have been involved in thyroid activity measurements.

A search has been performed of persons who had performed thyroid activity measurements in Kyiv. This search included:

- persons who have personally signed the lists with thyroid activity measurements;
- other persons who have been involved in measurement process;
- persons who have been involved in technical support of measurements (preparation of devices, control sources, collimators, etc.)

The following tasks have been set:

- to find out phone numbers and/or addresses of these persons;
- to organize personal meetings with these persons;
- to prepare, in view of these meetings, a list of questions concerning the peculiarities of measurements performed in 1986.

For measurements performed in Kyiv, the lists of primary documents carried the well legible names of 2 persons involved in measurements: Biryukova and Kashkadamov (Table 8.30.10). They have been found in the process of search. A personal meeting has been arranged with L.N. Biryukova, during which she informed us about the peculiarities of measurements performed with DSU devices on May 27-29, 1986, and SRP 68-01 on June 8, 1986. There has been a phone conversation with A.V. Kashkadamov, a personal meeting with him is being planned.

The signature of Fetisov V.R. (earlier referred to illegible ones) has been identified; so far his present address or phone number have not been found out.

Signatures have been identified on lists N 77/326, 77/327 ("T...Sy..." - Syvachenko T.P.); her phone number has been found and a personal meeting with her is being planned.

It has been established that the collimator for SRP 68-01 S/N 4256 and S/N 274 was made by the engineer Zaichenko A.V. During a personal meeting he informed us about the performances of the collimator and its using.

In the process of search of devices used for monitoring, the following persons provided a great help in searching the devices having been used for monitoring, searching the persons who performed measurements, and specifying the technical features of measurements:

Ovsiy V. EPSHTEIN - Head of the Laboratory of Functional Diagnosis of the Institute of Endocrinology and Metabolism, Kyiv.

Ihor A. KOVTUN - Head Physician of the Polyclinic of the town of Ukrainka, Obuhiv raion, Kyiv oblast.

Olena O. ODERIY - Head of Radiology Department of Kyiv Regional Hospital.

Yuriy O. RYBKIN - Engineer of Radiology Department of Kyiv Regional Hospital.

Valentyna V. SHYSHKINA - Professor of the Research Institute of Oncology and Radiology, Kyiv.

Yuriy O. TATSIY - Head of the Group of Radiation Protection of Kyiv Town Oncological Dispensary.

Volodymyr V. TRATSEVSKY - Collaborator of the Research Institute of Oncology and Radiology, Kyiv.

Raisa P. ZAKHARCHENKO - pensioner, former Head of the Radiology Department of Kyiv Regional Hospital.

Stanislav S. ZAMYATIN - Head of the Department of Radionuclide Diagnosis of Kyiv City's Oncological Dispensary.

In spite of difficulties in searching the persons involved in thyroid activity measurements, we consider it necessary to continue this work and to extend it to other regions of Ukraine where in 1986 thyroid activity measurements have been performed. Information obtained in the process of search and questioning will be reflected in appropriate chapters of the Operation Manual.

Table 8.30.1 Specified list of types of devices which have been used for thyroid activity measurements.

Device type	Models having been used	Available technical documentation	Institution where devices of the model in question are avilable
GTRM	GTRM—01ts	Yes	Research Institute of Oncology and Radiology
DSU	DSU-68	Yes	State Institute of Professional Improvement
	DSU 2-1	No	Kyiv City's Oncological Dispensary
UR	UR 1-1	Yes	Kyiv Regional Hospital
	UR 1-3	No	
	UR 3-2	No	
NK-150	NK-150	No	
NK-350	NK-350	Yes	State Institute of Professional Improvement
NC-308	NC-308	Yes	State Institute of Professional Improvement
PRL	PRL	No	
SRP	SRP-68-01	Yes	Scientific Center for Radiation Medicine
DP-5V	DP-5V	Yes	Scientific Center for Radiation Medicine

Table 8.30.2 – Outline of performances of devices for which technical documentation has been collected

Device model	Device name from technical documentation	Purpose	Detector	Display of results	Peculiarities
GTRM-01c	Gamma-thyreo-ratiometer	Medical radiodiagnosis	Scintillator, crystal NaI (TI) ∅40*40mm	Digital display; in pulses accumulated for a given time interval; in % from control source	Possibility of automatic background deduction
UR 1-1	Radiodiagnostic system	Medical radiodiagnosis	4 autonomous detectors, scintillators NaI (TI) ∅63*63 mm	Pointer-type device, in pulse/s, outlet to digital counting device	4 autonomous meters of pulse rate, each meter being separately tuned on its own detector
DSU-68	Diagnostic scintillation system	Medical radiodiagnosis	Scintillator, crystal NaI (TI) ∅40*40mm; the kit may include an additional detector with crystal ∅63*63mm	Digital display; in pulses accumulated for a given time interval; pointer-type device, in pulse/s (used for tuning)	Distance - 20-25 cm – to calibration source and to the neck of the person measured, being recommended in the chapter “Operation” of the technical manual
NK-350	Automatic spectrometer	Multipurpose (medicine, industry)	Scintillator NaI (TI), ∅40*40 mm (detector ND-131/B); The kit may include other models of detectors, made by “Gamma” plant	Digital display; in pulses accumulated for a given time interval; pointer-type device, in pulse/s (used for tuning)	Possibility of automatic background deduction; possibility of connecting several models of detectors to detector’s connector
SRP 68-01	Scintillation device for geological prospecting	Geology, Radiometric ground survey	Scintillator, crystal NaI (TI) ∅30*25 mm	Pointer-type device, in pulse/s and μR/h	Counting of results from upper and lower scales of a pointer-type device, in values pulse/s or in μR/h, is to be made depending on the position of band switch.
DP-5V	Dose rate meter	Radiometric ground survey	2 Geiger-Muller counters (respectively, for low- and high intensity gamma – radiation)	Pointer-type device, in mR/h	In one of 3 positions of detector’s jacket the device displays, together with gamma-radiation, beta radiation from superficial contamination

Table 8.30.3 – Thyroid activity measurements using GTRM devices

Device	Place of measurements	Serial number	Days of measurements
GTRM-01c	Lviv oblast	19	5/30
	Chernihiv oblast	32	5/24 – 5/30, 6/1, 6/27
		87	5/24 – 5/31
	Zhytomyr oblast	93	5/27 – 5/30, 6/2 – 6/6, 6/10
		94	5/27 – 6/3, 6/11, 6/13,-6/14, 6/16 – 6/21, 6/23 – 6/27, 6/30
	Odessa oblast	3981	5/17 – 5/21, 5/23, 5/24, 5/26, 5/27

Table 8.30.4 – Thyroid activity measurements using DSU devices

Device	Place of measurements	Serial number	Supposed serial number	Days of measurements
DSU 2-1	Khmelnytsky oblast	80910		5/28
	Crimea	107017		5/18 – 5/20, 5/21 – 5/24, 5/26
	City of Kyiv	107037		5/21 – 5/24, 5/26 – 5/29
DSU-68	Chernihiv oblast	14		5/26, 5/27, 5/29
		without number	14	5/30 – 5/31
	Vinnytsya oblast	1213		5/26 – 5/29

Table 8.30.5 – Thyroid activity measurements using UR devices

Device	Place of measurements	Serial number	Days of measurements
UR 1-1	Crimea	10242	5/20 – 5/23, 5/26 – 5/30, 5/26 – 5/30, 6/2, 6/3, 6/6
UR 3-2		11023	5/19 – 5/20
UR 1-3	Chernihiv oblast	912001	5/17 – 5/19
	Kyiv oblast		5/22 – 5/26
	Lviv oblast		5/29 – 5/31

Table 8.30.6 – Thyroid activity measurements by means of mobile radiometric laboratory (PRL)

Place of measurements	Days of measurements
Kyiv oblast	5/8, 5/12
City of Kyiv	5/15

Table 8.30.7 – Thyroid activity measurements using DP-5V devices

Device	Place of measurements	Serial number	Days of measurements
DP-5V	Kyiv oblast	1613899	5/8, 5/11, 5/13, 5/15 – 5/16, 5/19, 5/24

Table 8.30.8 – Thyroid activity measurements using devices from "Gamma" plant (Budapest, Hungary)

Device	Place of measurements	Serial number	Conditional or supposed serial number	Days of measurements
NC-308	City of Kyiv	without number	308	5/19, 5/21 – 5/23, 5/26 – 5/27
NK-350	Crimea	without number	1	5/16 – 5/24, 6/11
		2		5/16 – 5/24
		76028		5/16, 5/19, 5/22, 5/27, 5/30
		82014		5/19 – 5/23, 5/24, 5/26
	Odessa oblast	8479		5/17 – 5/21, 5/23, 5/24, 5/26
	Lviv oblast	80041		5/30
	Chernihiv oblast	81031		5/19 – 5/22, 5/24 – 5/27, 6/4
NK-150	Kyiv oblast	without number	3	5/14 – 5/16, 5/18 – 5/20, 5/22
		71042		5/24, 5/25 – 5/28
	Sumy oblast	without number	4	5/30
	Chernihiv oblast	71070		5/20, 5/24, 5/25, 5/27, 5/29 – 5/31, 6/2 – 6/4
		71077	supposed S/N 71070	5/23
		71077		5/19, 5/20, 5/23, 5/26 – 5/29, 5/31
		without number	supposed S/N 71077	5/25, 5/30

Table 8.30.9 – Thyroid activity measurements using SRP-68-01 devices

Place of measurements	Serial number	Supposed or conditional serial number	Days of measurements
Vinnytsya oblast	59		5/26 – 5/28
	1272		5/26 – 5/28
Donetsk oblast	757		5/30
	985		5/30
	1009		5/30
	1022		5/30
	1050		5/30, 5/31
Zhytomyr oblast	125		5/17 – 5/18, 5/20 – 5/24, 5/28
	149		5/17 – 5/24
	without number	149	5/22 – 5/23
	268		5/7 – 6/5
	without number	268	5/17, 5/18, 5/23
	854		5/24 – 5/30, 6/2
	914		5/24 – 5/26, 5/29 – 5/31, 6/2
	1075		5/20, 6/1 – 6/5
	1239		5/24 – 5/31, 6/2
	1385		5/28 – 5/31
	2746		5/24 – 5/26, 5/29
	without number	1002	6/1, 6/2
	without number		5/16 – 5/19, 5/29
Zaporizhya oblast	950		6/6, 6/10, 6/16
	1515		6/9 – 6/12, 6/24 – 6/25
Kyiv oblast	298		5/23 – 5/25
	1380		5/29, 5/31, 6/9, 6/10
	1550		5/21 – 5/24
	Without number	1143	5/12

Continuation of Table 8.30.9 – Thyroid activity measurements using SRP-68-01 devices

Place of measurements	Serial number	Supposed or conditional serial number	Days of measurements
Crimea	43		5/21 – 5/24
	129		5/20, 5/22 – 5/24
	131		5/19, 5/21 – 5/24
	1119		5/30
	without number	1119	5/30
	1582		5/30
	1727		5/24, 5/26, 5/31, 6/2, 6/5
	1757		5/24, 5/26
	without number	1757	5/22 – 5/23
	without number	1001	6/11
Lviv oblast	530		5/30
Odessa oblast	90		5/17, 5/22, 5/23, 5/26, 5/27
	238		6/4
	863		5/17, 5/19, 5/20, 5/22 – 5/24, 5/29
	1034		5/21, 6/2
	1086		5/21 – 5/22
	1665		5/20, 5/23, 5/26 – 5/30
	1670		5/17, 5/22 – 5/25, 5/27 – 5/29, 5/31
	1677		5/20 – 5/24, 5/26 – 5/29
	1719		5/22 – 5/29, 6/5, 6/6
	1748		5/17 – 5/24, 5/26 – 5/29, 5/31
	1820		5/27, 5/28
	2085		5/17, 5/18, 5/20 – 5/24, 5/26 – 5/29
	2113		5/23, 5/24, 5/26 – 5/30
Rivne oblast	2298		5/27 – 5/30, 6/3, 6/4

Continuation of Table 8.30.9 – Thyroid activity measurements using SRP-68-01 devices

Place of measurements	Serial number	Supposed or conditional serial number	Days of measurements
Sumy oblast	890		5/31
	1300		5/27, 5/28
	3019		5/28 – 5/31
	without number	1301	5/27 – 5/29
	without number	1302	5/28
	without number	1303	5/28 – 5/30
Ternopil oblast	994		5/29
	2995		5/29
Khmelnytsky oblast	282		5/25, 5/28
	without number	282	5/24
	987		5/29 – 5/31
	1063		5/24, 5/25, 5/27
	1684		5/31
	1684		6/3, 6/4
	1784		5/28 – 5/30
	without number	1784	5/29
	70641		5/28 – 5/30
Chernihiv oblast	899		5/24 – 5/26
	906		5/24 – 5/27, 5/30, 5/31, 6/1
	without number	906	5/30
	935		5/31 – 6/1
	957		5/24 – 5/31, 6/1
City of Kyiv	274		6/17
	1143		4/30, 5/1, 5/3, 5/5 – 5/8, 5/12 – 5/17, 5/20, 5/22, 5/27, 5/29, 6/3, 6/4, 6/10
	4256		6/8

Table 8.30.10 – List of persons whose signatures have been identified under the results of measurements performed in the City of Kyiv

List's number	Primary signature in the list	Performed interpretation of signature	Comment
75/607, 78/590, 78/591, 78/592	Biryukova	Lidiya N. Biryukova, Head of the Polyclinic of Kyiv Town Clinical Endocrinological Hospital; in 1986 Physician of the IEM	A personal meeting took place
78/593, 78/588, 78/589, 81/587	Kashkadamov	Anatoliy V. Kashkadamov, pensioner; in 1986 collaborator of the IEM	A phone conversation took place; personal meeting is planned
77/326, 77/327	Signature «T...Sy...»	Tamara P. Syvachenko, pensioner; in 1986 Chairman at the Department of Medical Radiology of State Institute of Professional Improvement	A personal meeting is planned
79/961, 79/962, 79/964, 79/965, 80/963	Illegible signature	V.P.Fetisov; in 1986 engineer of Radioisotope Laboratory of Kyiv Regional Oncological Dispensary (pluralist)	It was impossible to identify present place of work, address, phone number